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ABSTRACT

To help urban, suburban, and rural tree owners know about air pollution's effects on trees and their tolerance and intolerance to pollutants, the USDA Forest Service has prepared this booklet. It answers the following questions about atmospheric pollution: Where does it come from? What can it do to trees? and What can we do about it? In addition, it provides a tentative list of known responses by both hardwoods and softwoods to various airborne pollutants. Tolerant, intermediate, or sensitive levels are indicated for each species (when known) with regard to sulfur dioxide, hydrogen fluoride, ozone, oxides of nitrogen, peroxyacetyl nitrate (pan), ethylene, 2-4-D, chlorine, hydrogen choloride, and mercury vapor. An explanation is made that variations should be anticipated because of genetic and environmental factors, the type and concentration of pollutant, the tree's nearness to the pollution source and length of exposure to the pollutant, and the tree's health, stage of growth, and genetic makeup. (BL)

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our air

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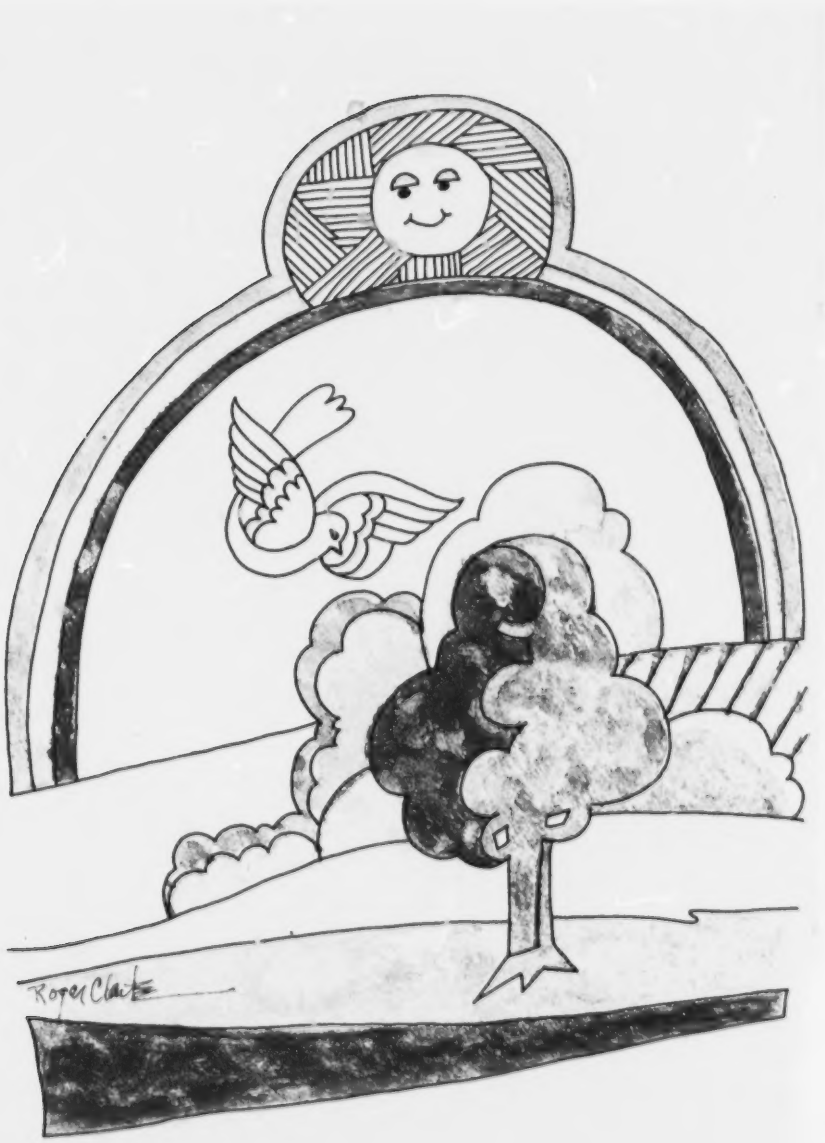
...unfit for trees


Roger Clai

"Fair is foul, and foul is fair:
Hover through fog and filthy air."
(Macbeth. Act 1, sc. 1, line 12).

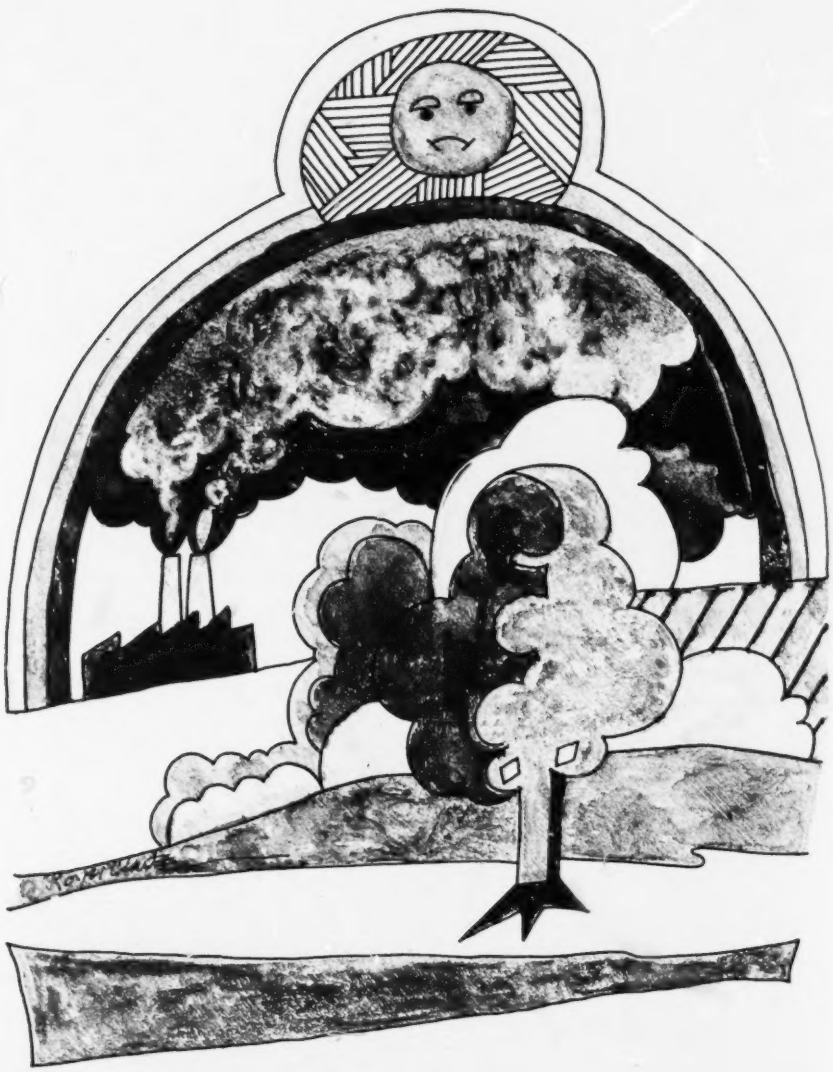
No, it didn't happen overnight. The problem of polluted air has been festering for centuries—witness Shakes, eare's Macbeth, 1605.

It's just that suddenly the problem of air pollution is becoming critical and is erupting in our sight. Not only do our eyes smart as they focus through murky air; but when the air clears, we see trees and vegetation succumbing. We must realize that this destruction can no longer be pinned to some mysterious cause. The one major culprit is air pollution.

Air Pollution: Where does it come from?

Today's air pollution is an unfortunate by-product of the growth of civilization and civilized man's desire for goods that require heavy industrialization and mass production. Machines and factories sometimes pollute and taint the air with substances that are dangerous to man and the environment. These include radioactive dust, salt spray, herbicide and pesticide aerosols, liquid droplets of acidic matter, gases, and sometimes soil particles. These substances can act alone to irritate objects and forms of life. Or, more dangerously, they join together to act upon the environment.

Only lately have we begun recognizing some of their insidious consequences.



Air Pollution: What can it do to trees?

Scientists have not yet been able to amass a complete report on the effects of air pollution on trees. They do know, however, that sulfur dioxide, fluorides, and ozone are the major tree despoilers and that individual trees respond differently to the numerous particulate and gaseous pollutants. Sometimes trees growing in a single area under siege by pollutants will show symptoms of injury or will die while their neighbors remain healthy. Scientists believe this difference in response depends on the kind of tree and its genetic makeup. Other factors, such as the tree's stage of growth and nearness to the pollution source, the concentration of pollutant, and the duration of the pollution onslaught will also play a part.

In short, whether or not a tree succumbs as a result of air pollution will depend on a combination of host and environmental factors.

For the most part, air pollutants injure trees through their foliage. Such foliar injury to conifers is generally more drastic than injury to hardwoods. It can cause conifers to lose their year-round needles prematurely. This precocious balding means that trees cannot maintain normal food-production levels. Undernourished and weakened, they are vulnerable to attack by a host of insects, diseases, and other environmental stresses; and death often follows.

Air pollution may also cause hardwoods to lose their leaves. But because their leaves are only borne for a portion of the year and are replaced the following year, air pollution injury to hardwoods may not be so severe.

Roger Cloutier

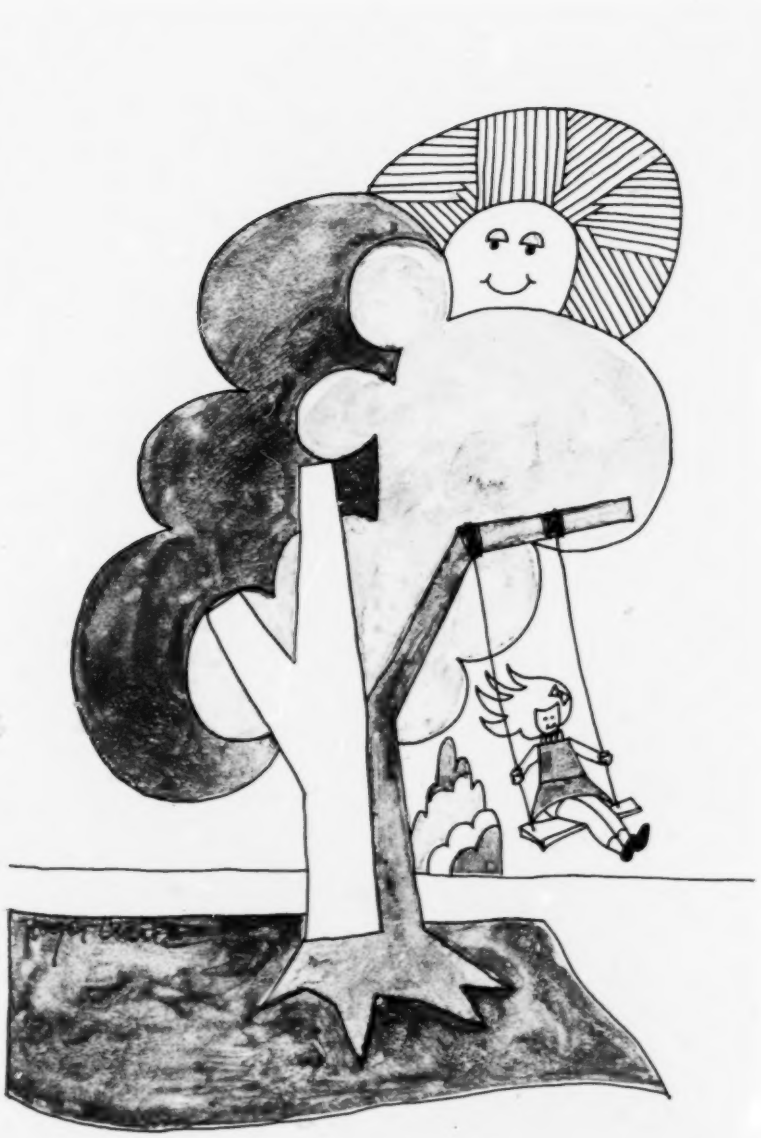
Air Pollution: What can we do about it?

Home and professional gardeners, landscapers, arborists, and foresters should be aware of the information available on the relationship between trees and air pollution. When undertaking a planting program, look out for nearby sources of pollution. Then plant only vegetation known to tolerate local pollutants.

You'll find that sulfur dioxide wastes are being emitted from industrial complexes. Sulfur dioxide originates from the combustion of nearly every fuel, but especially from coal and oil and from the heating of sulfide ores in the smelting process.

Industries and communities both discharge gaseous and particulate fluorides into the atmosphere from the smelting of nonferrous ores, steel, and aluminum; combustion of coal; manufacture of brick, ceramics, cement, glass, and phosphate fertilizers; production and use of hydrofluoric acid; and use of fluorides as oxidizing agents in rocket fuel. Fluorides are more damaging to vegetation than equivalent concentrations of other air pollutants. And fluorides in their gaseous form are more harmful than particulate fluorides.

You'll find ozone—better known as "smog"—enshrouding densely populated metropolitan areas; however, ozone damage has been spotted up to 100 miles away from any metropolitan source. Along with the combustion of automobile and industrial fuels, ozone is added to air by disturbances in the outer stratosphere of the earth and by electrical storms. Ozone probably causes more injury to plants than any other aerial toxicant in the United States.



The following list, representing the personal observations and reports of many international scientists, is a compilation of the known responses by both hardwoods and softwoods to various pollutants. Check this list before planting.

A "Tolerant" listing indicates that the tree species displays no sensitivity to a specific pollutant, but that its tolerance might be different under other genetic or environmental conditions. Resistant trees, by contrast, would show a total insensitivity to genetic non-susceptibility.

"Sensitive" trees respond to air pollution injury.

Trees of "Intermediate" sensitivity show some response to air pollutants, but they are not truly tolerant.

(This list should not be taken as an absolute basis for assessing the responses of trees to pollutants. Considerable local variation must be anticipated, because of genetic and environmental factors.) ➠

SULFUR DIOXIDE

SOFTWOODS	Tolerant	Intermediate	Sensitive
Balsam fir (Abies balsamea)		●	
White fir (Abies concolor)		●	
Silver fir (Abies pectinata)		●	
Lawson cypress (Cupressus lawsoniana)	●		
English holly (Ilex aquifolium)	●		
JUNIPER (Juniperus sp.)	●		
LARCH (Larix sp.)			●
Western larch (Larix occidentalis)			●
Engelmann spruce (Picea engelmannii)			●
White spruce (Picea glauca)	●		
Jack pine (Pinus banksiana)			●
Lodgepole pine (Pinus contorta latifolia)		●	
Western white pine (Pinus monticola)			●
Dwarf mugo pine (Pinus mugo mughus)	●		
Austrian pine (Pinus nigra)	●		
Ponderosa pine (Pinus ponderosa)			●
Eastern white pine (Pinus strobus)			●
Douglas fir (Pseudotsuga menziesii)		●	
White cedar (Thuja occidentalis)	●		
Western red cedar (Thuja plicata)	●		
Mountain hemlock (Tsuga mertensiana)			●

SULFUR DIOXIDE

HARDWOODS	Tolerant	Intermediate	Sensitive
Hedge maple (Acer campestre)	●		
Red maple (Acer rubra)	●		
Sugar maple (Acer saccharum)	●		
Mountain maple (Acer spicatum)	●		
BIRCH (Betula sp.)			●
White birch (Betula populifolia)			●
European hornbeam (Carpinus betulus)	●		
CATALPA (Catalpa sp.)			●
White dogwood (Cornus florida)	●		
European beech (Fagus sylvatica)	●		
Green ash (Fraxinus pennsylvanica)	●		
Maidenhair tree (Gingko biloba)	●		
English walnut (Juglans regia)			●
Tulip tree (Liriodendron tulipfera)	●		
APPLE (Malus sp.)			●
Texas mulberry (Morus microphylla)			●
Black gum (Nyssa sylvatica)	●		
Sourwood (Oxydendron arboreum)	●		
American planetree (Platanus occidentalis)	●		
Oriental planetree (Platanus orientalis)	●		
Balsam poplar (Populus balsamifera)		●	
Eastern cottonwood (Populus deltoides)	●		
Bigtooth aspen (Populus grandidentata)		●	
Lombardy poplar (Populus nigra 'Italica')			●
Quaking aspen (Populus tremuloides)			●
Pear (Pyrus communis)			●
English oak (Quercus robur)	●		
Red oak (Quercus rubra)	●		
Black locust (Robinia pseudoacacia)	●		
WILLOW (Salix sp.)			●
European mountain ash (Sorbus aucuparia)			●
American elm (Ulmus americana)			●

HYDROGEN FLUORIDE

SOFTWOODS	Tolerant	Intermediate	Sensitive
English holly (Ilex aquifolium)		●	
JUNIPER (Juniperus sp.)	●		
Western larch (Larix occidentalis)			●
White spruce (Picea glauca)	●		
Colorado spruce (Picea pungens)			●
Lodgepole Pine (Pinus contorta latifolia)			●
Dwarf mugo pine (Pinus mugo mughus)			●
Ponderosa pine (Pinus ponderosa)			●
Eastern white pine (Pinus strobus)			●
Scotch pine (Pinus sylvestris)			●
Loblolly pine (Pinus taeda)			●
Douglas fir (Pseudotsuga menziesii)			●
Japanese yew (Taxus cuspidata)		●	
ARBORVITAE (Thuja sp.)		●	

HYDROGEN FLUORIDE

HARDWOODS	Tolerant	Intermediate	Sensitive
Hedge maple (Acer campestre)		●	
Boxelder (Acer negundo)			●
Silver maple (Acer saccharinum)		●	
Tree of heaven (Ailanthus altissima)	●		
European black alder (Alnus glutinosa)	●		
European white birch (Betula pendula)		●	
Cutlead European birch (Betula pendula 'Gracilis')	●		
European hornbeam (Carpinus betulus)		●	
Spanish chestnut (Castanea sativa)		●	

HARDWOODS—CONTINUED	Tolerant	Intermediate	Sensitive
Cornelian cherry (Cornus mas)	●		
European filbert (Corylus avellana)		●	
Russian olive (Elaeagnus angustifolia)	●		
European beech (Fagus sylvatica)		●	
European ash (Fraxinus excelsior)		●	
Green ash (Fraxinus pennsylvanica)		●	
Modesto ash (Fraxinus velutina 'Modesto')	●		
Bleck walnut (Juglans nigra)		●	
English walnut (Juglans regia)		●	
Red mulberry (Morus rubra)		●	
PAULOWNIA (Paulownia sp.)			●
PLANETREE (Platanus sp.)	●		
Oriental planetree (Platanus orientalis)		●	
Lombardy poplar (Populus nigra 'Italica')		●	
Quaking aspen (Populus tremuloides)		●	
Eugene poplar (Populus canadensis eugenei)		●	
Flowering apricot (Prunus americana)			●
Flowering plum (Prunus cerasifera)	●		
Bradshaw plum (Prunus domestica 'Bradshaw')			●
Oriental cherry (Prunus serrulata)	●		
English oak (Quercus robur)		●	
Smooth sumac (Rhus glabra)		●	
Black locust (Robinia pseudoacacia)		●	
WILLOW (Salix sp.)	●		
European elder (Sambucus nigra)	●		
European red elder (Sambucus racemosa)	●		
European mountain ash (Sorbus aucuparia)	●		
American mountain ash (Sorbus domestica)	●		
American linden (Tilia americana)	●		
Little leaf linden (Tilia cordata)	●		
European linden (Tilia europaea)		●	
American elm (Ulmus americana)	●		

OZONE

SOFTWOODS	Tolerant	Intermediate	Sensitive
Balsam fir (Abies balsamea)	●		
White fir (Abies concolor)		●	
Western juniper (Juniperus occidentalis)	●		
European larch (Larix decidua)			●
Japanese larch (Larix leptolepis)			●
Incense cedar (Libocedrus decurrens)		●	
Norway spruce (Picea abies)	●		
White spruce (Picea glauca)	●		
Black Hills spruce (Picea glauca densata)	●		
Colorado spruce (Picea pungens)	●		
Knobcone pine (Pinus attenuata)		●	
Jack pine (Pinus banksiana)			●
Coulter pine (Pinus coulteri)		●	
Jeffrey pine (Pinus jeffreyi)			●
Sugar pine (Pinus lambertiana)	●		
Singleleaf pinyon pine (Pinus monophylla)	●		
Austrian pine (Pinus nigra)			●
Ponderosa pine (Pinus ponderosa)			●
Monterey pine (Pinus radiata)			●
Red pine (Pinus resinosa)	●		
Pitch pine (Pinus rigida)			●
Digger pine (Pinus sabiniana)	●		
Eastern white pine (Pinus strobus)			●
Scotch pine (Pinus sylvestris)			●
Torrey pine (Pinus torreyana)	●		
Virginia pine (Pinus virginiana)			●
Big cone Douglas fir (Pseudotsuga macrocarpa)		●	
Douglas fir (Pseudotsuga menziesii)	●		
Giant sequoia (Sequoia gigantea)	●		
Redwood (Sequoia sempervirens)	●		
ARBORVITAE (Thuja sp.)	●		
Eastern hemlock (Tsuga canadensis)			●

OZONE

HARDWOODS	Tolerant	Intermediate	Sensitive
Boxelder (Acer negundo)			●
Norway maple (Acer platanoides)	●		
Red maple (Acer rubra)	●		
Silver maple (Acer saccharinum)			●
Sugar maple (Acer saccharum)	●		
ALDER (Alnus sp.)			●
European white birch (Betula pendula)	●		
CATALPA (Catalpa sp.)			●
Judas tree (Cercis chinensis)			●
White dogwood (Cornus florida)	●		
White ash (Fraxinus americana)			●
Green ash (Fraxinus pennsylvanica)			●
Honeylocust (Gleditsia triacanthos)			●
Black walnut (Juglans nigra)	●		
Sweetgum (Liquidambar styraciflua)			●
Tulip tree (Liriodendron tulipfera)			●
Siberian crab (Malus baccata)			●
Maple leaf mulberry (Morus alba acerfolia)			●
American planetree (Platanus occidentalis)			●
California sycamore (Platanus racemosa)			●
Quaking aspen (Populus tremuloides)			●
White oak (Quercus alba)			●
Scarlet oak (Quercus coccinea)			●
Gambel oak (Quercus gambelii)			●
Shingle oak (Quercus imbricaria)	●		
Pin oak (Quercus palustris)			●
English oak (Quercus robur)	●		
Red oak (Quercus rubra)	●		
Black locust (Robinia pseudoacacia)			●
Weeping willow (Salix babylonica)			●
European mountain ash (Sorbus aucuparia)	●		
Little leaf linden (Tilia cordata)			●

OXIDES OF NITROGEN

SOFTWOODS	Tolerant	Intermediate	Sensitive
European larch (Larix decidua)		●	
White spruce (Picea glauca)			●
Colorado spruce (Picea pungens)			●
Dwarf mugo pine (Pinus mugo mughus)			●
Austrian pine (Pinus nigra)			●
Eastern white pine (Pinus strobus)			●

PEROXYACETYL NITRATE (PAN)

SOFTWOODS	Tolerant	Intermediate	Sensitive
European larch (Larix decidua)	●		
Japanese larch (Larix leptolepis)	●		
White spruce (Picea glauca)	●		
Colorado spruce (Picea pungens)	●		
Jack pine (Pinus banksiana)	●		
Austrian pine (Pinus nigra)	●		
Pitch pine (Pinus rigida)	●		
Eastern white pine (Pinus strobus)	●		
Douglas fir (Pseudotsuga menziesii)	●		
Eastern hemlock (Tsuga canadensis)	●		

ETHYLENE

SOFTWOODS	Tolerant	Intermediate	Sensitive
Japanese holly (Ilex crenata)			●
ARBORVITAE (Thuja sp.)			●

OXIDES OF NITROGEN

HARDWOODS	Tolerant	Intermediate	Sensitive
Japanese maple (Acer palmatum)			●
Norway maple (Acer platanoides)			●
European hornbeam (Carpinus betulus)			●
European beech (Fagus sylvatica)			●
Maidenhair tree (Gingko biloba)			●
APPLE (Malus sp.)			●
Pear (Pyrus communis)			●
Black locust (Robinia pseudoacacia)			●
European elder (Sambucus nigra)			●
Little leaf linden (Tilia cordata)			●
Large leaf linden (Tilia grandiflora)			●

PEROXYACETYL NITRATE (PAN)

HARDWOODS	Tolerant	Intermediate	Sensitive
Sugar maple (Acer saccharum)	●		
Tulip tree (Liriodendron tulipfera)			●
Little leaf linden (Tilia cordata)			●

2-4-D

SOFTWOODS	Tolerant	Intermediate	Sensitive
HICKORY (Carya sp.)			●
Colorado spruce (Picea pungens)		●	
YEW (Taxus sp.)		●	
HEMLOCK (Tsuga sp.)		●	

CHLORINE

SOFTWOODS	Tolerant	Intermediate	Sensitive
Chinese holly (Ilex chinensis)	●		
Jack pine (Pinus banksiana)		●	
Short leaf pine (Pinus echinata)		●	
Eastern white pine (Pinus strobus)			●
Loblolly pine (Pinus taeda)		●	
YEW (Taxus sp.)	●		
HEMLOCK (Tsuga sp.)	●		

2-4-D

HARDWOODS	Tolerant	Intermediate	Sensitive
Boxelder (Acer negundo)			●
Norway maple (Acer platanoides)			●
Tree of heaven (Ailanthus altissima)			●
BIRCH (Betula sp.)			●
HICKORY (Carya sp.)			●
American Yellowwood (Cladrastis lutea)			●
DOGWOOD (Cornus sp.)			●
ASH (Fraxinus sp.)	●		
Sweetgum (Liquidambar styraciflua)		●	
APPLE (Malus sp.)			●
MULBERRY (Morus sp.)		●	
London planetree (Platanus acerifolia)			●
Pin oak (Quercus palustris)		●	
Red oak (Quercus rubra)		●	
Black oak (Quercus velutina)			●
LINDEN (Tilia sp.)			●

CHLORINE

HARDWOODS	Tolerant	Intermediate	Sensitive
Boxelder (Acer negundo)			●
Sugar maple (Acer saccharum)			●
Horse chestnut (Aesculus hippocastanum)			●
Tree of heaven (Ailanthus altissima)			●
Russian olive (Elaeagnus angustifolia)	●		
Sweetgum (Liquidambar styraciflua)			●
APPLE (Malus sp.)			●
Black gum (Nyssa sylvatica)		●	
Black cherry (Prunus serotina)		●	
Pin oak (Quercus palustris)			●
Red oak (Quercus rubra)	●		
Sassafras (Sassafras albidum)			●

HYDROGEN CHLORIDE

SOFTWOODS	Tolerant	Intermediate	Sensitive
Balsam fir (Abies balsamea)	●		
LARCH (Larix sp.)			●
Norway spruce (Picea abies)	●		
Austrian pine (Pinus nigra)	●		
Eastern white pine (Pinus strobus)	●		
ARBORVITAE (Thuja sp.)	●		
HARDWOODS	**Tolerant**	**Intermediate**	**Sensitive**
MAPLE (Acer sp.)	●		
Norway maple (Acer platanoides)	●		
Sugar maple (Acer saccharum)	●		
BIRCH (Betula sp.)	●		
CHERRY (Prunus sp.)			●
Black cherry (Prunus serotina)	●		
Pear (Pyrus communis)	●		
OAK (Quercus sp.)	●		
Red oak (Quercus rubra)	●		

MERCURY VAPOR

SOFTWOODS	Tolerant	Intermediate	Sensitive
Chinese holly (Ilex chinensis)	●		
Eastern white pine (Pinus strobus)			●
HARDWOODS	**Tolerant**	**Intermediate**	**Sensitive**
Japanese maple (Acer palmatum)		●	
Persimmon (Diospyros virginiana)		●	
MIMOSA (Mimosa sp.)			●
OAK (Quercus sp.)		●	
WILLOW (Salix sp.)			●

For over 75 years, the USDA Forest Service through its 8 regional research stations with numerous field laboratories, like the one in Delaware, Ohio, has overseen forestry research programs aimed at protecting, managing, using, and replenishing our forest resources. The Northeastern Forest Experiment Station is one of these regional research stations.

The Northeastern Station is responsible for a wide variety of research studies from diagnosing air pollution injury in trees to the control and eradication of oak wilt and Dutch elm diseases . . . integrated control of the gypsy moth . . . restoration of surface-mined coal lands . . . and the development of America's first concerted research effort at urban forestry.

Besides such research the USDA Forest Service cooperates with state agencies and private forest owners to stimulate proper management practices and to protect the 440 million acres of their forests against fires, insects, and diseases.

The Forest Service also manages 187 million acres of public land, including 154 National Forests and 18 National Grasslands in 43 states and Puerto Rico. Each National Forest resource—timber, water, forage, fish and wildlife, and recreation—is managed to produce a harmonious environment along with tangible benefits for all of America's people.

This booklet is based, in part, on the air pollution research work of USDA Forest Service Plant Pathologist Dr. Leon S. Dochinger of the Forest Insect and Disease Laboratory in Delaware, Ohio. At Delaware the Forest Service is engaged in research work aimed at determining the responses of hardwoods and softwoods to the various pollutants. Through this research the Forest Service is helping trees make life more tolerable on earth for man—in this century, as well as in the next century.

GIVE A HOOT!
DON'T POLLUTE

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